DEBRIS FLOWS OR LAVA FLOWS ON MARS? SHAPES OF TERRESTRIAL COUNTERPARTS MAY HELP IDENTIFY FLOWS IMAGED IN UPCOMING MISSIONS. G. Michaels, R. Greeley, Department of Geology, Arizona State University, Tempe, AZ 85287-1404; e-mail gm@asu.edu.

Summary. With the increased camera resolution of Mars Global Surveyor and other upcoming missions, it is likely that more lobate deposits will be imaged in greater detail. Many of these deposits will turn out to be lava flows, but others may be debris flow deposits indicating the presence of water on Mars. It has been postulated that lahars (debris flows of volcanoclastic sediments) exist nearby Elysium Mons [1,2,3] and constitute the Medusae Fossae Formation [3]; that the aureole associated with Olympus Mons may be related to the flow of lahars [3]; that Hadriaca [3,4], Tyrrhena [4,5], Apollinaris [4] and Alba Paterae [4,6], and Ceraunius [4] and Hecates Tholi [4,7] may have experienced magma-water interaction; and that debris flows may have descended from the walls of Valles Marineris [8]. However, if martian debris flows resemble their terrestrial counterparts they should consist of thin deposits showing subtle brightness differences with their surroundings and very little relief. Additionally, most of the characteristic landforms associated with debris flows are too small to be imaged at resolutions of planetary imaging systems. Furthermore, the areal extent of most terrestrial debris flows is considerably smaller than the proposed Elysium Mons lahar deposits. If martian flows are similar to terrestrial flows they may have been undetected in Viking Orbiter images, but may be detected in upcoming missions. We are developing an understanding of morphological characteristics of terrestrial debris flows from air photos of the lahars of Mount St. Helens, Washington; Mount Augustine, Alaska; and Klyuchevskii, Kamchatka and the debris flows in Owens Valley, California, as well as from descriptive accounts of these and other debris flow deposits. Our research focuses on a quantitative analysis of the margins of terrestrial flow deposits, including rhyodacite, andesite and basalt lavas, debris flows, pyroclastic flows and debris avalanches. To analyze these flows we use an algorithm to generate curvature spectra, a measure of the abundance of all orders of *radius* of curvature (RC) within a margin. The results are somewhat analogous to Fourier spectra but can be adapted to highly irregular, digitate margins. The spectra are then examined for consistent differences between different types of flows, and variations within one type. Variation is expected among debris flows due to differences in grain size and the size distribution of debris, bulk sediment, clay and water concentration, and underlying topography.

Background. Qualitative observations of morphologies of terrestrial debris flows document that some of the most characteristic features are thin deposits [9, 10, 11], levees [10,12,13,14,15] and lobate termini studded with the largest clasts [10,14,16], and planar [17] to gently undulating surfaces [9,16]. In some examples surfaces contain unsorted boulders and cobbles [18] decreasing in frequency down-gradient [16]; oblique lobes protrude from levees [12,16]; pits are present from escaping steam [19], withdrawal of water [20] or melting of ice clasts [21]; longitudinal grooves are present [22]; larger hummocks are present [22,23]; and small distal erosional channels form from dewatering [10,16]. Although planform shapes are variable, many examples widen down-gradient from a narrow source, and some diverge into digitate lobes with large length/widths and constant widths. Many debris flows begin channelized, a characteristic which assists in their initial mobility [15,16,18,24]; some actually channelize themselves with their own levees [10,12,16]. Debris flows easily migrate into topographic valleys because of their low yield strengths. Our study avoids channelized debris flows to the extent possible because the unchannelized flow margin reflects the flow rheology and characteristics unique to its emplacement.

Methodology. Although it is important to understand the qualitative characteristics of debris flows to aid in their recognition, our study is concerned with an objective, quantitative characterization that is a direct reflection of flow rheology, emplacement mechanism, and basal slope. Air photos with resolutions greater than 1m were obtained for each type of flow deposit. Flows were selected which are relatively pristine, unconfined by valleys, free of large obstructions, and on basal slopes between 1° and 30°.

Once the margins of the flow deposits are digitized from enlarged airphotos, our algorithm generates the curvature spectra. The algorithm involves a few simple steps which are implemented repeatedly: (1) measuring RC for every group of three points (in overlaping sets), (2) comparing each RC to a threshold RC, (3) "smoothing" or moving the center point to reduce RC for any three points that are under the threshold, so that they may conform to the threshold, and (4) measuring the total length of the digitized stream of points after all RCs conform to the threshold. Then the algorithm moves to the prespecified, next largest threshold and repeats the same steps. The end result is a plot (Figs.a-e) of *change* in margin length (y-axis) verses RC threshold (x-axis). These "curvature spectra" are in essence the magnitude of curvature verses the abundance of this curvature in the flow margin.

Results. Initial results show that debris flows have curvature spectra that are different from those of other flows. Results have been binned for simplicity of comparison. Debris flows (Fig.a) are distinct from rhyodacite (Fig.b) and andesite (Fig.c) flows which have an absence of small RC. Basalt (Fig.d), debris and pyroclastic (Fig.e) flows, which all contain small RC features, can be distinguished from one another by certain differences in their spectral patterns. Debris flows and pyroclastic flows have more spikes in their spectra than do basalts. This is

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partly an affect of the long digitate fingers in debris and pyroclastic flows. Pyroclastic flows have the peak of their small RC spectra at an RC of about 1 meter, whereas debris flows and basalts have the peak of their small RC at about 10 meters. Although results are preliminary, these initial differences allow us to separate debris flows from other types of flows. We intend to better quantify these differences and test more examples.

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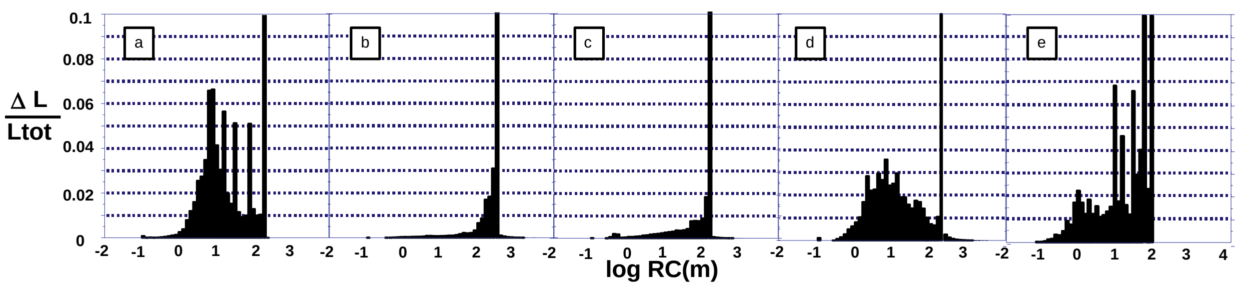

Curvature spectra of (a) a lahar deposit, Mt. Shasta, CA; (b) a rhyodacite lava flow, South Sister Peak, OR; (c) an andesite lava flow, Mt. St. Helens, WA; (d) an aa basalt lava flow, Mauna Ulu, HI; (e) a pyroclastic flow, Mt. St. Helens, WA.